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PROGRAMME OF THE

STANFORD MEETING

AT

STANFORD UNIVERSITY, CALIFORNIA

December 29 and 30, 1949

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DECEMBER 29, 1949 Vol. 24, No. 8

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STANFORD MEETING, DECEMBER 29 AND 30, 1949

THE 296th meeting of the American Physical Society will be held at Stanford University on Thursday and Friday, December 29 and 30, 1949. Invited papers will be given by M. Chodorow, M. Skinner, E. Teller, B. Zimm, R. Penndorf, A. B. Meinel, and C. T. Elvey. The Friday afternoon session will be held in the Little Theater. The other sessions will be held in the Physics Building.

The **Registration Desk** will be located in the arcade near Rooms 370 and 372, Physics Department. These are the rooms where most of the contributed papers will be given. Information and maps will be available there, and messages may be left for persons attending the meeting.

Rooms. Dormitory accommodations will be available in Lagunita Hall (women's dormitory) for the nights of December 28, 29, and 30. All rooms must be vacated by 8 A.M. on December 31. Since students are not asked to clear their rooms between quarters, some personal belongings may be in evidence. Those arriving during the evening of December 28 should go to Lagunita Hall where a receptionist will be in attendance from 4 P.M. until midnight. All rooms are double; it is asked that no request be made for single rooms, although if there is not enough demand some rooms may be available for single occupancy. The rate per person is $3.00 for one night, $5.50 for two nights, and $8.00 for three nights. Requests for room reservations must be accompanied by the names of the persons concerned, the nights of occupancy, and a check payable to Stanford University for the full amount. These can be sent to the Physics Department at Stanford and must be received by December 1. Since other conferences are being held on the campus at this time, there will be some competition for room space. Attention is called to the University regulation against the possession or use of liquor in University properties.

In addition to the accommodations at Lagunita Hall, there are several motor courts along El Camino Real and Bayshore Highway near Palo Alto, and the President Hotel and Cardinal Hotel in Palo Alto.

Meals. Breakfast, lunch, and dinner will be available at the Stanford Union Cafeteria on December 29 and 30.

Transportation. Transportation between Lagunita Hall, the meeting rooms, and Stanford Union is not essential, since the distances are easy walks. However, most people will want transportation from the Greyhound Bus Depot or Palo Alto Railroad Station, where the distance is a mile to a mile and a half, depending upon the part of the campus which is to be reached; taxis can be obtained at the stations. The Morning Daylight (Southern Pacific train) from Los Angeles (change at San Jose), which arrives at Palo Alto Station at 5:44 P.M., will be met on the evening of December 28, if requested. Please indicate with your reservation if you wish to be met then.

Post-deadline papers. The Council, availing itself of an amendment to the By-Laws adopted on 30 January 1948, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of papers of which the abstracts are received not later than Friday, December 23." These abstracts must reach the office of Dr. J. Kaplan (University of California, Los Angeles 24, California) by the specified time. Do not regard this as a guarantee of acceptance! The idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are accepted will not be published: the titles will be announced, and the papers will be scheduled for presentation at a convenient time or times during the meeting.

Prospective meetings of the Society are scheduled as follows: New York, February 2–4, 1950; Oak Ridge, Tennessee, March 16–18; Washington, D. C., April 27–29; Mexico City, June 21–24.

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General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of each invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session will be announced by the Secretary at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in fewer than ten minutes, or may read it by title.

Titles and abstracts of the papers contributed to the Stanford meeting are printed in the following pages. Proofs of the abstracts have not been submitted to the authors, and the proofreading is always cursory because of the need for haste: but the authors have opportunity to correct their proofs before the abstracts appear in the Physical Review. Overlong abstracts sometimes appear in a form unexpected by the authors, because there is not time to consult them before the abstracts are amputated to fit the requirements stated on the summons card.

Acknowledgment. The Secretary wishes to acknowledge the excellent help of Professors L. I. Schiff and F. Bloch in arranging the program of invited papers and in the general planning of the meeting.

J. Kaplan
Local Secretary for the Pacific Coast
University of California
Los Angeles 24, California

PROGRAMME

THURSDAY MORNING AT 10:00

Room 100, Physics Department

(COMMANDER EUGENE BOLLAY presiding)

Invited Papers

A1. The Sodium Flash during Twilight. R. PENNDORF, *Directorate for Geophysical Research U. S. Air Force.* (30 min.)

A2. Progress in Upper Air Research at N.O.T.S. C. T. ELVEY, *U. S. Naval Ordnance Test Station, Inyokern.* (30 min.)

A3. The Near-Infra-Red Spectrum of the Night Sky and Aurora. A. B. MEINEL, *Lick Observatory.* (30 min.)

Contributed Paper

A4. Infra-Red Spectra of the Night Sky, Aurora and Afterglows.* JOSEPH KAPLAN, *University of California, Los Angeles.*—Meinel's recent spectroscopic studies of night sky and aurora in the infra-red made with a grating spectrograph and hypersensitized Eastman I–N plates are discussed in the light of infra-red studies of nitrogen and oxygen afterglows by Kaplan. The most significant result of this comparison is the suggestion that the atmospheric system of O_2, first observed in emission in the night sky by Meinel, and in a laboratory afterglow by Kaplan, originates below 100 km at a level where recombination of normal oxygen atoms can proceed rapidly enough to account for these bands. This is based on the high intensity of the atmospheric bands which originate on $v=0$, in both night sky and afterglow and the proposal that the remarkable enhancement of $v=0$ in the laboratory is a criterion for excitation by atomic recombination. It is also suggested that diffuse bands due to NO_2, also observed in the laboratory afterglow, will account for other unidentified radiations in the night sky between λ4000 and λ9000.

* Work done under contract with ONR.

THURSDAY AFTERNOON AT 2:00

Room 370, Physics Department

(R. T. BIRGE, presiding)

Invited Paper

B1. The Study of High Polymer Molecules by Light Scattering. BRUNO H. ZIMM, *University of California, Berkeley.* (30 min.)

Contributed Papers

B2. The Differential Equations of Nuclear Induction.[1] F. BLOCH AND R. K. WANGSNESS,* *Stanford University.*—The phenomenon of nuclear induction has been originally[2] described by a system of differential equations, intended to give the qualitative features of the observed signals in terms of two characteristic relaxation times. A rigorous quantum-statistical method has been devised to investigate the limits of validity of these equations. Based upon the generally valid Boltzmann equation for the density matrix, it is shown that the simpler original equations for the components of the nuclear polarization are likewise generally valid for nuclei with spin $\frac{1}{2}$ and valid for higher spin if the coupling of the nucleus with the surroundings at temperature T is due to its magnetic dipole and if $H\mu \ll hT$. Other cases of the validity of these equations, as well as cases, where they are not applicable, are discussed.

[1] Work assisted by the Joint Program of the ONR and AEC.
* AEC Predoctoral Fellow.
[2] F. Bloch, Phys. Rev. **70**, 460 (1946).

B3. Coincidence Studies on the Decay of Hf^{181}.* W. C. BARBER, *Stanford University.*—In spite of a considerable amount of work on the decay scheme of (Hf^{181}),[1–4] there is no general agreement as to the assignment of the excited states of the product nucleus, Ta^{181}. In the present work coincidence measurements, employing anthracene and stilbene scintillation counters, have been made on the Hf^{181} radiations in the hope of making a fairly complete description of the Ta^{181} levels. The results of these measurements to date include the following: (1) Energetic electrons ($E_0>0.25$ Mev), having the absorption properties of nuclear β-rays, are found in coincidence with hard γ-rays ($E\sim 0.4$ Mev). Experiments employing delayed coincidences show these radiations to be time coincident to within 10^{-8} second, thus ruling out the decay scheme proposed by Wiedenbeck and Chu,[2] where the β-decay of Hf^{181} leads directly to the 22 μsec. metastable state first detected by DeBenedetti and McGowan.[1] (2) γ-rays of energy approximately 0.4 Mev are found in coincidence with softer

γ-rays, which by absorption appear to consist of 140-Kev γ-rays and K x-rays of Ta. The time delay between these transitions is also 10^{-8} sec. or less, indicating that this 140-Kev transition is not from the metastable state.

* Assisted by the Joint Program of ONR and AEC.
[1] S. DeBenedetti and F. K. McGowan, Phys. Rev. **74**, 728 (1948).
[2] K. Y. Chu and M. L. Wiedenbeck, Phys. Rev. **75**, 226 (1949).
[3] J. Benes *et al.*, Nature **162**, 261 (1948).
[4] E. N. Jensen, Phys. Rev. **76**, 958 (1949).

B4. The Magnetic Moment of the Proton in Units of the Nuclear Magneton. C. D. JEFFRIES, *Stanford University.*—An experiment in progress to measure directly the ratio of the proton magnetic moment μ_P to the nuclear magneton μ_N is described. The method has been suggested by Alvarez and Bloch[1] and consists essentially in performing two experiments in the same homogeneous magnetic field: (1) An experiment in which the Larmor precession frequency ω_L of a spinning proton is observed; (2) an experiment in which the "cyclotron" frequency ω_C of a revolving proton is observed. Then $\mu_P/\mu_N = \omega_L/\omega_C$. The Larmor frequency is measured by the method of nuclear induction.[2] The apparatus for measuring the cyclotron frequency will be described and preliminary results will be reported.

[1] L. W. Alvarez and F. Bloch, Phys. Rev. **57**, 111 (1940).
[2] F. Bloch, Phys. Rev. **70**, 460 (1946).

B5. Chemical Analysis by Proton Scattering. S. RUBIN, *Stanford Research Institute,* AND V. K. RASMUSSEN, *California Institute of Technology.*—The dependence of the velocity of initially monoenergetic scattered protons on the mass of the scattering nucleus has been applied to the analysis of minute samples of unknown substances. The velocity spectrum of the elastically scattered protons is measured with a high resolution magnetic spectrograph, giving the identification and relative proportions of the elements in the target. Under suitable conditions, this technique can be used to detect and identify elements in surface concentrations as low as 10^{-10} g/cm^2. Much higher resolution is required to identify heavy elements than light ones. It has been calculated that the resolution of all elements should be possible, if the accelerator voltage can be regulated to one part in 12,000 for proton bombardment, or one part in 3000 for alpha-particle bombardment, with corresponding spectrograph resolution. With the available apparatus, elements up to $Z \sim 30$ have been resolved. Analyses have been made of samples obtained by depositing thin layers of airborne particulate matter on beryllium and aluminum backings by means of a jet impactor, for air pollution studies. The principal advantage of such an analytical method is that it makes it possible to use spot-sampling devices even for very dilute contaminants.

B6. A Nuclear Induction Radiofrequency Spectrometer.* W. G. PROCTOR AND F. C. YU, *Stanford University.*—A nuclear induction[1] apparatus has been made into a recording spectrometer similar in principle to one developed by Pound.[2] The steady magnetic field is modulated by a small sweep while the common frequency of the receiver and transmitter is slowly changed by a clock drive. When the frequency is correct for resonance, the Fourier component of the signal at the sweep frequency is proportional to the derivative of the resonance mode being observed; if the receiver output is detected by a lock-in amplifier, this derivative is plotted by a recording d.c. milliameter. The spectrometer has been in use at Stanford for about a year and has been used to determine the magnetic moments, signs and spins of a number of isotopes. New experimental results will be given.

* Assisted by the Joint Program of the AEC and the ONR.
[1] F. Bloch, Phys. Rev. **70**, 460 (1946).
[2] R. V. Pound, Phys. Rev. **72**, 637 (1947).

B7. Design and Construction of an X-Ray Microscope. ALBERT V. BAEZ AND PAUL KIRKPATRICK, *Stanford University.*—A reflection type x-ray microscope has been constructed for use with the soft x-rays from a General Electric diffraction tube with chromium target. Glass mirrors, both uncoated and metal coated, are used. Uncoated mirrors have the better polish but smaller critical angles. Elliptical mirrors have been built up by selective metallic condensation on glass. The figure of such mirrors is good but the surface finish is inferior. The optical system consists of two mirrors set close together with their faces at right angles in a manner hitherto described. A single-stage magnification, adjustable from 50 to 100 diameters, is obtained. Air absorption is avoided by filling the microscope with helium at one atmosphere. Objects and films may be changed without important loss of time or gas. Focusing is accomplished by varying the angles of incidence while watching the images on a fluorescent screen. Performance tests are in progress.

B8. High Energy Deuteron Break-Up. L. I. SCHIFF, *Stanford University.*—It is shown that the leading term in the asymptotic expansion of the matrix element of a multipole operator between ground-state deuteron wave function ($l=0$) and plane wave for high plane wave energy depends only on a particular term in the expansion of the deuteron potential energy about the origin. If this potential has the form $MV(r)\hbar^2 = A_{-1}/r + A_0 + A_1 r + A_2 r^2 + \cdots$, and the ground-state deuteron wave function $R(r)$ is normalized to unity at the origin, then

$$\int R(r) r^l P_l(\cos\theta) e^{ikr\cos\theta} d\tau_{\mathbf{k}} \to \infty \frac{4\pi i^{l+s+3}}{2^{l+1} k^{l+s+5}} \times \frac{\Gamma(s+2l+5)\Gamma(\frac{1}{2}s+2)}{(s+2)(s+3)\Gamma(\frac{1}{2}s+l+3)} A_s,$$

where s is the smallest *odd* number for which $A_s \neq 0$. This result is of interest in connection with the high energy photoeffect of the deuteron and deuteron breakup by π^--meson capture. For explicit calculations at all energies it is convenient to use a potential for which the ground-state wave function has a simple analytic form. A wide variety of such potential shapes is found by assuming a sufficiently flexible form for $R(r)$ and inverting the wave equation. These potentials can be chosen to be monotonic, with various behaviors near the origin; they fall off exponentially for large r.

B9. Nuclear Induction Apparatus for Observing Signals in Gases. M. E. PACKARD, *Stanford University.*—In order to measure nuclear relaxation times in gases, it is advantageous to observe the line structure in detail. To aid in these measurements, a nuclear induction apparatus has been developed with a signal-to-noise ratio which is adequate for observing signals from protons in gases at moderate pressures, directly on a cathode-ray oscillograph. The apparatus uses an electromagnet which has been especially shimmed to give a field which is homogeneous to within 0.02 gauss out of 10,000 gauss over the sample area. The signal is preamplified by a grounded-cathode grounded-grid type of r-f amplifier which gives a good noise figure. For quantitative measurements, the noise band width is reduced without sacrificing detail by photographically averaging the signal over many sweep cycles. The apparatus has been built with r-f circuits which can be simultaneously tuned to two frequencies so that the gyromagnetic ratios of two gases in a mixed sample can be measured in exactly the same magnetic field.

B10. Semiconductors as Low Temperature Thermometers. I. ESTERMANN, *Carnegie Institute of Technology.**—The large temperature coefficient of the resistivity of semiconductors suggests their usefulness as secondary thermometers. Above room temperature, elements containing semi-conducting oxide mixtures (thermistor thermometers)[1] are satisfactory, but their resistance at low temperatures is too high for practical

applications. Very pure elementary semiconductors, such as germanium and silicon, show a non-linear current voltage relationship at low temperatures and internal rectification.[2] A study of the resistivity of 13 germanium and 4 silicon samples with varying amounts of additions between 1.8°K and 20°K indicates that germanium samples with a resistivity of the order of 0.05 ohm-cm at room temperature are free from these undesirable properties. Below 4°K their resistivity can be expressed by an equation of the form $h=A\exp(\theta/T)$. Typical values of the temperature coefficient of resistance are: 0.8 percent at 70°K, 1.7 percent at 20°K, 2.5 percent at 4°K, and 16.5 percent at 2°K. Temperature measurements to 0.001°K can easily be carried out. Reproducibility after warming up to room temperature was 0.01°K, but it is expected that this figure can be reduced considerably.

* This work was carried out at the National Bureau of Standards with assistance by an O.N.R. contract.

[1] Becker, Green, and Pearson, Trans. A.I.E.E. **65**, 711 (1946).
[2] Estermann, Foner, and Zimmerman, Phys. Rev. **75**, 1631 (1949); Gerritsen, Physica **XV**, 427 (1949).

B11. The Polarization of Starlight. LEVERETT DAVIS, JR., *California Institute of Technology*.—The observed[1,2] polarization of starlight, which is associated with the reddening produced by interstellar dust, could be explained by the fact that the small dust grains, which are probably not spherical, preferentially weaken that part of the light for which the electric vector is parallel to the long axis of the grain. However, one must find some mechanism that will partially align the rapidly spinning grains. The only suitable field seems to be a galactic magnetic field, **B**. The grains should contain a few percent iron atoms and hence their a.c. susceptibility might have a significant imaginary part. Because of energy dissipation, their short axes would then tend to become parallel to **B**. The disorienting effect of the collisions of ions of mass m with the grains of mass M is assumed to have a relaxation time $\tau M/m$, where τ is the mean time between collisions. With these assumptions, a uniform field of 3×10^{-5} gauss might produce the observed polarization. Since the planes of polarization are nearly parallel for stars separated by 300 light years, **B** must be approximately homogeneous over very large regions.

[1] J. S. Hall, Science **109**, 166 (1949).
[2] W. A. Hiltner, Astrophys. J. **109**, 471 (1949).

THURSDAY AFTERNOON AT 2:00

Room 372, Physics Department

(J. KAPLAN, presiding)

C1. Production of Mesons by X-Rays, Part I: Experimental Method. R. STEPHEN WHITE, EDWIN M. MCMILLAN, AND JACK M. PETERSON, *University of California, Berkeley*.—A preliminary study has been made of the π^-/π^+ ratio, the energy distribution of π-mesons, and the cross section for production of π-mesons observed at angles near 90° to the beam direction. Mesons were produced by the collimated x-ray beam which traversed a 1 by 3-inch cylindrical carbon target. The mesons were detected in stacks of Ilford C-2 nuclear plates of 100 micron emulsion thickness placed azimuthally about the target behind appropriate lead absorbers. The x-ray beam was monitored by means of an ionization chamber. The maximum densities of mesons obtained were about 100 mesons per square centimeter. The exposures were limited by the single grain background. The distribution of mesons with depth in the emulsion was uniform except for 10 microns nearest each surface. The angular distribution of π-mesons was compatible with isotropic emission from a finite line source. The distribution of μ^+-mesons in angle with the beam direction was found to be isotropic. From separate plots of ρ- and σ-mesons *versus* angle to the beam direction a ratio for π^-/σ was obtained which is compatible with the value of Adelman and Jones.[1] This work was performed under the auspices of the AEC.

[1] F. L. Adelman and S. B. Jones, Phys. Rev. **A75**, 1468 (1949).

C2. Production of Mesons by X-Rays, Part II: Experimental Results. JACK. M. PETERSON, EDWIN M. MCMILLAN, AND R. STEPHEN WHITE, *University of California, Berkeley*.—The ratio of the number of negative to that of positive π-mesons produced in carbon by the x-rays from the 335-Mev electron synchrotron is not observed to have any statistically significant variation with energy in the range 30 to 150 Mev; the average value is 1.7 ± 0.2. This value is considerably different from our first published value of 10.[1] A part of this difference may be real, since the original value was found under different conditions; however, a considerable part of the difference probably comes from the less reliable technique employed earlier. An energy spectrum of mesons emitted near 90° to the x-ray beam has been measured from 20 to 150 Mev, the lower limit being set by the thickness of the carbon target. The spectrum has a maximum near 35 Mev. The integral of the spectrum leads to a total cross section of 5×10^{-28} cm² per carbon nucleus per "quantum" plus or minus a factor of two. Mesons have been observed also with the synchrotron operated at 200 Mev; the meson energy distribution extends only to about 35 Mev and the yield is considerably less than at 335 Mev. This work was sponsored by the AEC.

[1] E. M. McMillan and J. M. Peterson, Science **A109**, 438 (1949).

C3. Production of Mesons by X-Rays, Part III: Theory. KEITH A. BRUECKNER, *University of California, Berkeley*.—Calculations have been made by Feshbach[1] and Foldy[2] on the production of scalar, pseudoscalar, and vector mesons by photons. Perturbation theory in the weak coupling approximation was used and the nucleons were treated non-relativistically. The calculations have been redone including all relativistic effects and extended to the case of pseudovector mesons. The results obtained vary critically with the type of meson theory used. Comparison with the experimental results of McMillan, Peterson, and White indicates that the pseudoscalar theory gives the most acceptable predictions of angular and energy distributions and of the magnitude of the cross section. The mesons of spin one are excluded because of their strong coupling to the high energy components of the photon spectrum. The scalar meson theory gives a strongly anisotropic angular distribution in contrast with that observed. It is further found that the excess of negative over positive mesons observed is predicted by all of the theories and is due to the current carried by the nucleons. This work was sponsored by the AEC.

[1] Herman Feshbach and Melvin Lax, Phys. Rev. **76**, 134 (1949).
[2] Leslie L. Foldy, Phys. Rev. **76**, 372 (1949).

C4. Transition Curves in Lead of X-Rays, Causing Nuclear Reactions. I. Experimental. K. STRAUCH, *University of California, Berkeley.*—Polystyrene and copper foils stacked between lead absorbers were bombarded with the synchrotron x-ray beam using maximum energies of 200 and 335 Mev. The foil activities produced by the reactions $C^{12}(\gamma, n)C^{11}$ and $Cu^{63}(\gamma, n)Cu^{62}$ were measured and plotted against depth in lead. The resulting transition curves of those photons responsible for these reactions show (1) an initial drop due to photon absorption; (2) a maximum due to multiplication by the cascade process; (3) an exponential decrease. The area under these curves or "track length," determines a mean energy of photons causing these reactions. Preliminary calculations give energy values of 20 and 30 Mev for the copper and carbon reactions respectively; this is in agreement with the excitation curves measured by Baldwin and Klaiber.[1] This method is being used to measure the mean photon energies causing several reactions: $Zn^{64}(\gamma, n)Zn^{63}$, $Zn^{64}(\gamma, 2n)Zn^{62}$, $Zn^{64}(\gamma, pn)Cu^{62}$, $Al^{27}(\gamma, 2pn)Na^{24}$, $Ta^{181}(\gamma, ?)$60 minutes. Results will be presented. This work was supported by the AEC.

[1] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **73**, 1156 (1948).

C5. Transition Curves in Lead of X-Rays Causing Nuclear Reactions. II. Theoretical. L. EYGES, *University of California, Berkeley.*—The transition curves obtained by Strauch can be explained quantitatively by the cascade theory of showers. This theory can be made to give a fairly accurate expression for the total area under the transition curves, i.e., the "track length" corresponding to the mean energy of the photons responsible for the reactions observed. The behavior of the transition curve at its beginning (up to about 1 radiation length) can also be calculated fairly accurately, and this behavior gives a check on the mean photon energy as determined by the track length. The shape of the whole transition curve can also be calculated although with somewhat less accuracy, but within the limits of error the shape agrees with the experimental results. This work was sponsored by the AEC.

C6. Design of the Bevatron Quarter Scale Operating Model. D. C. SEWELL, W. M. BROBECK, E. O. LAWRENCE, AND E. J. LOFGREN, *University of California, Berkeley.*—The model Bevatron magnet is constructed of ½-inch thick laminations with a 13¼×41-inch aperture which is centered with an 11½-foot radius. It is pulsed 20 times per minute by a 540 kw d.c. flywheel generator. The field rises to a peak of 1000 gauss in 200 milliseconds; this allows a proton energy of 6½ Mev. The magnet is divided into four quadrants which are spaced 5 feet from one another at the ends. A 0.7-Mev proton beam from a 20-inch cyclotron is deflected electrostatically into the machine at one of these straight sections. The 23-inch long r-f accelerating electrode is placed in the straight section diametrically opposite the injection point. Movable horizontal and vertical defining vanes are in the remaining two straight sections. Probes for monitoring the beam can be moved radially into the beam from the inner radius at the quadrant ends. The vacuum tube has a 9½×39½-inch aperture and is built of 0.031-inch thick stainless steel. It is constructed in 5 degree sections that are insulated from one another to minimize eddy current effects. This development was sponsored by the AEC.

C7. Bevatron Model Radiofrequency System. Q. A. KERNS, W. R. BAKER, G. M. FARLY, AND J. RIEDEL, *University of California, Berkeley.*—A saturable-reactor tuned oscillator at the magnet shunt drives a self-tracking power amplifier at the accelerating electrode. The ferroxcube reactor is temperature controlled to ±.1°C, and the main saturating winding is a single loop of manganin threading the cores and soldered directly across the 0.001 ohm shunt. Oscillator frequency is linear to 1 percent with magnet current over a 3:1 frequency range. The frequency slope varies with the $L-C$ ratio and with the fractional magnet current through an additional loop of 10±1 times the main loop resistance. Frequency level adjustment and corrections of up to ±5 percent are obtained by controlling the current in an auxiliary 35 turn saturating winding as a suitable function of shunt voltage. The amplifier output tube load is a larger ferroxcube reactor resonating with the 400 $\mu\mu f$ accelerating electrode capacity. Phase discriminator control of the saturating current to this reactor gives automatic tuning from .38 to 1.4 mc. Plate voltage modulation permits r-f voltages up to 1900 peak, and 50–2000 μsec. rises of adjustable curvature. This work was sponsored by the AEC.

C8. Bevatron Model Operating Results. E. J. LOFGREN, W. M. BROBECK, E. O. LAWRENCE, D. C. SEWELL, *University of California, Berkeley.*—The model bevatron (proton synchrotron) has accelerated protons from 0.7 Mev to 6½ Mev. About 10^{-8} coulombs are injected from a cyclotron in a 1 μsec. pulse every 4 seconds. With the tank diaphragmed to aperture of 6×18 inches ¼ percent of the ions attain the final energy. If the tank aperture is increased to 9×26 inches, the beam is increased by a factor 7. If it is decreased to 4½×16 inches the beam is reduced by a factor 9. Normal tank pressure is 2.10^{-6} mm. The beam decreases exponentially with tank pressure and is reduced to $1/e$ by a pressure change of $1.7 \cdot 10^{-6}$ mm. The final energy of the protons may be varied by changing the duration of the r-f pulse. The resulting beam *vs.* final energy curve is nearly flat after 4 Mev. The minimum required accelerating voltage is 600 and the beam increases nearly linearly with r-f volts to 1400 after which it is constant to 1900, the highest available. Sponsored by the AEC.

C9. Theoretical Discussion of the Performance of the Model Bevatron. LLOYD SMITH, A. A. GARREN, AND L. R. HENRICH, *University of California, Berkeley.*—Measurements obtained from the bevatron model provide a basis for comparing the operation of an actual machine with the general theory of the proton synchrotron. The sensitivity of the accelerated beam to variation in magnetic field at injection, starting frequency, dee voltage and other parameters can be interpreted consistently in terms of the size, shape and location of the phase stable region. Some conclusions may also be drawn about frequency tracking, loss of ions due to scattering and the effect of straight sections on the orbits of the ions—problems which are peculiar to the bevatron. Here also the effects are in reasonable agreement with the theoretical estimates. This work was done under the auspices of the AEC.

C10. An Experiment for Measuring Heavy Meson Production by High Energy Particles. H. A. WILCOX AND C. RICHMAN, *University of California, Berkeley.*—An experimental method has been devised for measuring the heavy-meson production cross section of nuclei bombarded by charged particles from the Berkeley synchro-cyclotron. A target composed of the material to be studied is inserted in the external beam of the cyclotron. The beam is integrated after it has traversed the target. Positive and negative π-mesons leave the taget with various energies E_π and at various angles θ to the direction of the beam. Blocks of Al and Cu are arranged so that the mesons leaving at any given angle θ are stopped in these blocks at positions determined by the kinetic energies with which they started. Nuclear emulsions are embedded in the blocks to sample the population of stopped mesons. The observed mesons are identified as positive if they give rise to a μ-decay, and as negative if they produce a nuclear star. From the numbers of π^+- and π^--mesons observed in the various regions of these emulsions, the differential production cross sections σ_+ and σ_- (in cm^2 Mev^{-1} steradian^{-1} per target nucleus) are inferred as functions of the angle θ and meson energy E_π. This work was sponsored by the AEC.

C11. Measurement of the Production of Positive and Negative π-Mesons by 345-Mev Protons on Carbon. C. RICHMAN AND H. WILCOX. *University of California, Berkeley.*—The method for measuring the production of mesons that we described[1] has been applied to the production in carbon. Thin graphite targets were bombarded by the 345-Mev external proton beam produced by the Berkeley 184-inch synchrocyclotron. The mesons coming off at 90° to the beam were observed at the ends of their ranges by means of C-3 nuclear emulsions embedded in suitable aluminum and copper blocks. The beam was integrated. The energy spectrum of mesons from carbon at this angle has a broad maximum at around 35 Mev. It drops off on both sides of this maximum, and on the high energy side extends up to about 140 Mev. The cross section for the combined production of positive and negative π-mesons at the maximum is $(2.9\pm0.7)\cdot10^{-30}$ cm^2 Mev^{-1} steradian^{-1} per carbon nucleus. The cross section integrated over meson energy is $(2.1\pm.6)\cdot10^{-28}$ cm^2 steradian^{-1} per nucleus. These cross sections are uncorrected for nuclear absorption in the blocks. The ratio of positive to negative π-mesons from carbon, obtained by integrating the positive and negative spectra separately over meson energy, has a value of 4.5 ± 2. This work was sponsored by the AEC.

[1] H. A. Wilcox and C. Richman, previous paper.

C12. Measurement of Production of Positive and Negative π-Mesons in Lead by 345-Mev Protons. MITCHEL WEISSBLUTH, *University of California, Berkeley.*—The experimental arrangement described by Wilcox and Richman[1] was used to obtain the spectrum of positive and negative π-mesons emitted by lead when bombarded by 345-Mev protons. Mesons were observed in C-3 nuclear emulsions at 90° to the beam direction. The combined spectrum of positive and negative mesons extends to about 120 Mev with a peak at about 30 Mev. The cross section at the peak is $(2.1\pm.4)\times10^{-29}$ cm^2 Mev^{-1} steradian^{-1} per lead nucleus. The cross section integrated over meson energy at 90° is $(8.9\pm2.4)\times10^{-28}$ cm^2 steradian^{-1} per nucleus. These cross sections are uncorrected for nuclear absorption in the blocks. Comparison of the peak cross section for lead with that for carbon[2] shows that they are consistent with the assumption that these cross sections are approximately proportional to the geometrical cross sections of the two nuclei. The ratio of positive to negative mesons from lead, obtained by integrating each spectrum separately over meson energy, is 1.5 ± 1. This work was sponsored by the AEC.

[1] H. A. Wilcox and C. Richman, paper presented at this meeting.
[2] C. Richman and H. A. Wilcox, paper presented at this meeting.

C13. Energy and Angular Distribution of π-Mesons Produced by 350-Mev Protons. T. B. TAYLOR* AND G. F. CHEW, *University of California, Berkeley.*—The energy and angular distributions of π-mesons produced by 350-Mev protons have been calculated on the assumption that the matrix element for the process is a constant. The cases of target nucleons which are free or which are bound in nuclei are considered. A heavy nucleus is considered to be a degenerate Fermi gas of neutrons and protons. A model which takes into account the finite size and mass of the nucleus is used for light nuclei. Interference effects, Coulomb effects, and the possibility that mesons will be scattered by nucleons on their way out of the nucleus have been neglected. The shapes of the calculated energy distributions agree with experimental distributions from carbon[1] and from lead[2] for meson energies for which Coulomb effects are unimportant. The orders of magnitude of the matrix elements calculated near threshold from various present meson theories are the same,[3] and these give cross sections of the same order of magnitude as those measured. This work was sponsored by the AEC.

* Now at Los Alamos Scientific Laboratory.
[1] C. Richman and H. A. Wilcox (accompanying abstract).
[2] M. Weissbluth (accompanying abstract).
[3] K. A. Brueckner (private communication).

C14. Nuclear Disintegration under Different Absorbers. H. SUN AND HARRIET H. FORSTER, *University of Southern California.*—Kodak and Ilford nuclear emulsion plates have been used to measure the attenuation of the star producing radiation under lead and paraffin. The photographic plates, completely surrounded by the adsorber, were exposed to the cosmic radiation at an altitude of 30,000 ft. Data will be presented showing the rate of occurrence of stars under the various absorbing materials and under varying thicknesses of lead. The results show an exponential absorption of the star producing radiation for large thicknesses of lead, with a corresponding absorption depth of about 250 g/cm^2; a transition effect of the star producing radiation has been found to occur within the first two centimeters of lead.

FRIDAY MORNING AT 9:30

Room 370, Physics Department

(F. BLOCH, presiding)

D1. The Positive-Negative Ratio for π-Mesons Produced in Company Nuclei. GEOFFREY F. CHEW AND JACK L. STEINBERGER, *University of California, Berkeley.*—Energies available from existing accelerators are not sufficiently high to warrant the treatment of meson production, in the bombardment of complex nuclei by neutrons and protons, as a two-nucleon process only. A theoretical investigation of the effect of the other nucleons present has been undertaken, particularly as regards the positive-negative π-meson ratio. It will be shown that the exclusion principle leads to a favoring of positives over negatives when the incident particle is a proton and *vice versa* when it is a neutron. The effect should increase with meson energy at a fixed incident nucleon energy and decrease with incident nucleon energy at a fixed meson energy. Calculations for the special case of the deuteron will be reported, to show the probable order of magnitude of the effect.

D2. Meson Mass Measurements. F. M. SMITH, WALTER H. BARKAS,* A. S. BISHOP, HUGH BRADNER, AND EUGENE GARDNER, *University of California, Berkeley.*—This is the third progress report on a program for measuring meson masses at the 184-inch Berkeley cyclotron, the first two reports having been given at meetings of the American Physical Society at Berkeley[1] and Seattle.[2] Mass values announced at the Berkeley meeting were based on range-energy data of Lattes, Fowler, and Cuer.[3] Recent range-energy measurements of Bradner *et al.*[4] are more pertinent to the present problem, and the previous mass values have been corrected. Also, other small

corrections have been made. Present best values are: $m_\tau = 276 \pm 6$, $m_\mu = 210 \pm 4$ electron masses. A program is in progress to measure meson masses by comparison with the proton mass. It is thought that this method will give more accurate values than the method used previously. No results from this study are available yet. This work was sponsored by the AEC.

* ONR, San Francisco, California.
[1] E. Gardner, Phys. Rev. **75**, 1468 (1949); A. S. Bishop, Phys. Rev. **75**, 1468 (1949); C. M. G. Lattes, Phys. Rev. **75**, 1468 (1949).
[2] Bishop, Bradner, and Smith, Phys. Rev. **76**, 588 (1949).
[3] Lattes, Fowler, and Cuer, Proc. Phys. Soc. (London) **59**, 883 (1947).
[4] Bradner, Barkas, Smith, and Bishop, Phys. Rev. (to be published).

D3. Observations on Tracks in Electron Sensitive Emulsions. FRANK L. ADELMAN, *University of California, Berkeley.*—Low ionization tracks from π-meson stars have been studied with Ilford G-5 emulsions. Only about 2 percent of the star prongs were found to be heavy particles of lower ionization than 30-Mev protons, in contradiction to hypotheses of Marshak[1] and Fujimoto, Hayakawa, and Yamaguchi.[2] The energy was estimated by grain counting, with the assumption that the grain density of a 10–100-Mev proton is inversely proportional[3] to its velocity. Some electrons were found to be associated with meson endings. However, the heavy random grain and low energy electron background tends to mask high energy electron tracks and to make the definite assignment of a low energy electron to a star or star prong generally uncertain. The numbers of prongs per star agreed within the statistical errors with the work of Adelman and Jones.[4] The investigation reported here is being continued. This work was sponsored by the AEC.

[1] R. Marshak, Abstract for Echo Lake Cosmic-Ray Symposium (1949).
[2] Fujimoto, Hayakawa, and Yamaguchi, Prog. Theor. Phys. (in press).
[3] B. Blau, Phys. Rev. **75**, 279 (1949).
[4] F. L. Adelman and S. B. Jones, Phys. Rev. **75**, 1468(A) (1949).

D4. Nuclear Cross Sections for X-Rays from the Berkeley Synchrotron. A. C. HELMHOLZ AND K. STRAUCH, *University of California, Berkeley.*—The x-rays from the 335-Mev electrons accelerated in the Berkeley synchrotron have been used to produce radioactive elements by (γ, n), $(\gamma, 2n)$, and (γ, pn) reactions. The use of thin foils and β-ray standards has provided the number of radioactive atoms per unit beam irradiation. The relative cross sections for the total x-ray beam, assuming that for $C^{12}(\gamma, n)C^{11}$ is 1.0 are: $Cu^{63}(\gamma, n)14$; $Cu^{65}(\gamma, n)17$; $Zn^{64}(\gamma, n)12$; $Zn^{64}(\gamma, 2n)1.6$; $Zn^{64}(\gamma, pn)3$. The ratio $(\gamma, n)/(\gamma, 2n)$ is in qualitative agreement with that from the measurements of Perlman and Friedlander.[1] The large value of (γ, pn) is surprising and is being further investigated. Using a $1/E$ spectrum for the x-rays, measurements of the energy flux by Blocker and Kenney,[2] and 20 Mev for the effective x-ray energy, we find a preliminary value for the $Cu^{63}(\gamma, n)$ cross section of 10^{-24} cm^2 Mev, in agreement with that of Lawson and Perlman.[3] Portions of this work have been sponsored by the AEC.

[1] M. L. Perlman and G. Friedlander, Phys. Rev. **74**, 442 (1948).
[2] W. Blocker and Robert W. Kenney, Abstract No. D8.
[3] J. L. Lawson and M. L. Perlman, Phys. Rev. **74**, 1190 (1948).

D5. Observations on Grain Counting and the Photographic Emulsion. J. KENT BOWKER, *University of California, Berkeley.*—Following the grain-counting technique of other experimenters[1–3] a study was conducted to find the mass of the negative π-meson. The thirty-six mesons and seven protons counted were registered in Ilford C-2, 100 μ-emulsions exposed in such a manner that the particles enter the edge of the emulsion and are stopped within 4 mm. The mass of the meson was found to be $264\left(\begin{smallmatrix}+26\\-22\end{smallmatrix}\right)m_e$. The large spread in masses led to an examination of the emulsion, which revealed a sensitivity variation in the region where the particles were found. Subsequently many other plates were exposed to particles of light, and the number of developed grains was counted or measured photometrically. A study showed that the sensitivity is greatest at an edge and decreases to uniformity only after 4 mm from that edge. Mean grain-counts of mesons at the edge and in the center of a plate were found to differ by as much as 5 percent. This paper is based on work performed with the support of the AEC.

[1] Lattes, Occhialini, Powell, Proc. Phys. Soc. **61**, 173 (1948).
[2] Barkas, Gardner, and Lattes, Phys. Rev. **74**, 1558(A) (1948).
[3] L. Van Rossum, Comptes Rendus **228**, 676 (1949).

D6. Production of C^{11} and C^{12} by High Energy Particles. LEE AAMODT, VINCENT PETERSON, AND ROBERT PHILLIPS, *University of California, Berkeley.*—The absolute cross section as a function of proton energy for the reaction $C^{12}(p, pn)C^{11}$ has been measured from threshold to 350 Mev using protons from the Berkeley 32-Mev linear accelerator and from the deflected beam of the 184-inch cyclotron. Polystyrene foils were counted in beta-counters calibrated against Na^{24} and Au^{198} coincidence standards, and against RaE standards. The proton current was integrated by means of suitable Faraday cups and low leakage condensers. The cross section has a broad peak of about 80 mb at 60 Mev and falls to one-half this value by 350 Mev. The usual "stacked-foil" technique cannot be used with 350-Mev protons because of high absorption in copper ($\sigma_a \sim 0.8$b) used to degrade the proton energy. Measurements of the absorption of protons in carbon are also being made to correct the published relative excitation curves for the reactions $C^{12}(d, dn)C^{11}$ and $C^{12}(\alpha, \alpha n)C^{11}$,[1] and $C^{12}(p, pn)C^{11}$ in the intermediate energy region[2] which were determined using stacked carbon disks. Absolute values of the (d, dn) and $(\alpha, \alpha n)$ cross sections for 190-Mev deuterons and 380-Mev alphas will be given. This work was sponsored by the AEC.

[1] R. L. Thornton and R. W. Senseman, Phys. Rev. **72**, 872 (1947).
[2] W. W. Chupp and E. M. McMillan, Phys. Rev. **72**, 873 (1947).

D7. The Beta-Spectra of Zn^{62} and Cu^{62}. RAYMOND W. HAYWARD, *University of California, Berkeley.*—The beta-spectra of Zn^{62} and Cu^{62} have been investigated in a magnetic lens type spectrograph. The Zn^{62} formed by a $Cu^{63}(d, 3n)Zn^{62}$ reaction in the 184-inch cyclotron decays with a half-life of 9.2 hours, thus offering a convenient method of investigating its 10.1 minute half-life daughter Cu^{62} which decays in equilibrium with the Zn^{62}. Analysis according to the Fermi theory yields a straight line Fermi yields a straight line Fermi plot for the Cu^{62} spectrum with an upper energy limit of 2.92 ± 0.01 Mev and upon subtraction of the Cu^{62} contribution a straight line plot is also obtained for the Zn^{62} spectrum with an upper energy limit of 0.665 ± 0.010 Mev. The relative number of disintegrations of the Zn^{62} and Cu^{62} indicates that the Zn^{62} decays 10 percent of the time by positron emission and the remainder by K-capture. In addition, two conversion peaks are found corresponding to the K and L conversion peaks of a 41.8 ± 0.4-kev gamma-ray following the Zn^{62} decay. From the ratio of the number of K and L conversion electrons it is found that the transition is of either an electric or magnetic dipole type. This work was assisted by the AEC.

D8. Showers Initiated by 335-Mev Bremsstrahlung. WADE BLOCKER AND ROBERT W. KENNEY, *University of California, Berkeley.*—The variation of cascade shower intensity with depth has been determined for showers produced in lead, copper, aluminum, and carbon by the 335-Mev bremsstrahlung from the Berkeley synchrotron. The collimated beam from the synchrotron passed through a monitor ionization chamber and fell normally upon closely stacked plates of the element under study. The shower particles from various thicknesses of this element were then observed by a detector ionization chamber situated behind the plates. An essentially infinite amount of the element under study was placed behind the detector chamber to provide backscattered radiation. This

contribution to the total intensity was very considerable in the case of lead. Shower intensities in the initial half-radiation length allow the thin-layer pair production and Compton contributions to the shower to be derived. The ordinates and abscissae of the maxima of the shower curves are compared with theory. The exponential tails of the shower curves give the gamma-ray absorption coefficients at the energy of minimum absorption cross section. These values are compared with theory. A thin sheet of lead observed by an ionization chamber gave ionization values which are used to derive the total energy of the x-ray beam. This work was sponsored by the AEC.

D9. A Fast Neutron Spectrometer Employing Li^6 Impregnated Emulsions. G. R. KEEPIN, JR.* AND J. H. ROBERTS, *Northwestern University.*—Observation of $Li^6(n, \alpha)H^3$ within an impregnated emulsion provides an accurate measure of both energy and direction of the incident neutrons. Preliminary studies using thermal neutrons have been reported [1] Calibration with monoenergetic neutrons indicates resolution of at least ± 75 kev for $0 < E_n < 2$ Mev. Given E_n and θ, the laboratory angle between alpha and triton tracks, two triton energies are possible from the conservation laws. Similarly there are two values of $R_\alpha + R_t$, the sum of alpha and triton ranges. We identify the larger value as the case favoring the triton, f_t, the smaller as the f_α case. E_n, regarded as a function of θ and $R_\alpha + R_t$, is least sensitive for f_t disintegrations with $\theta \simeq 180°$. Thus, for maximum energy resolution we select only f_t disintegrations with $175° \leq \theta \leq 180°$. Continuous spectra must be corrected for the energy dependence of: (1) probability that $175° \leq \theta \leq 180°$, (2) Li^6 cross section, and (3) geometrical selection criteria. The Li^6 technique is uniquely suited to measurements inside a material medium where perturbations introduced by the detector must be minimized and where collimation is impossible.

* Now at Radiation Laboratory, University of California, Berkeley.
[1] G. R. Keepin, Jr., and J. H. Roberts, Phys. Rev. **76**, 154 (1949).

D10. Measurement of Protons Produced in the Synchrotron Beam. A. SILVERMAN AND C. LEVINTHAL, *University of California, Berkeley.*—A proportional counter telescope with two counters each with an active region of one and one-half inches diameter and one and one half-inches deep is used in coincidence. By adjusting separate pulse height discriminators in each counter, the system may be used to count protons entering the first counter with energies between 1.5 and approximately 5 Mev. The resolving time of the system is approximately 0.5 μsec. With the synchrotron beam spread out over two milliseconds, the time resolution and pulse height discrimination combined with adequate shielding reduces the electron γ-ray background to a small fraction of the proton counting rate. The energy distribution arising from several different elements will be discussed. This work was sponsored by the AEC.

D11. Excited States of the Mirror Nuclei Be^7 and Li^7. A. B. BROWN, C. Y. CHAO, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.**—A low energy group of α-particles has been found to result from the reaction $B^{10}(p, \alpha)Be^{7*}$, indicating the existence of an excited state of Be^7. Observation of this group, which has not previously been found, and separation of the group from protons elastically scattered by the thin B^{10} targets was made possible through high resolution magnetic analysis supplemented by absorption techniques. A broad resonance is indicated near 1.5-Mev proton energy. The Q-values of the reactions leading to the ground state and to the excited state were found to be 1.145 ± 0.005 Mev and 0.710 ± 0.007 Mev, respectively. The excited state thus is 0.435 ± 0.008 Mev above the ground state. On the basis of approximately equal neutron-neutron and proton-proton forces, plausible arguments[1] can be advanced which indicate that this state corresponds to the excited state in Li^7 at 0.478 Mev.

* This work was assisted by the Joint Program of the ONR and the AEC.
[1] Fowler, Delsasso, and Lauritsen, Phys. Rev. **49**, 561 (1936).

D12. Gamma-Radiation from an Excited State of Be^7.* T. LAURITSEN AND R. G. THOMAS,† *California Institute of Technology.*—In earlier work at this laboratory[1] a γ-ray line at 420 kev was reported to appear in the bombardment of B^{10} with protons and was attributed to excitation by inelastic scattering of a state of B^{10} at that energy. After the discovery, by Brown *et al.*[2] of a group of α-particles corresponding to the formation of Be^7 in an excited state in the reaction $B^{10}(p\ \alpha)Be^{7*}$, the γ-radiation was re-examined in the magnetic lens spectrometer and compared more carefully with the 414-kev line[3] in $Be^9(d\ n)B^{10*}$ with the result that the two γ-ray energies were found to differ by 15 kev, yielding 429 ± 5 kev for the Be^{7*} line.[4] The excitation function and absolute cross section for this radiation agree well with those found for the α-particle group. In a search for the corresponding radiation from $Li^6(d\ n)Be^{7*}$, a target of Li^6SO_4 was bombarded with 1450-kev deuterons. The line at 429 kev appeared, together with the well-known line at 478 kev from $Li^6(d\ p)Li^{7*}$, with an intensity very nearly equal to the latter.

* This work was assisted by the Joint Program of the ONR and the AEC.
† AEC Fellow.
[1] Lauritsen, Fowler, Lauritsen, and Rasmussen, Phys. Rev. **73**, 636 (1948).
[2] A. B. Brown, *et al.* (preceding abstract).
[3] Rasmussen, Hornyak, and Lauritsen, Phys. Rev. **76**, 581 (1949).
[4] We are indebted to the AEC for the loan of the B^{10} metal and the enriched Li^6SO_4 used in these experiments.

D13. Gamma-Radiation from $C^{13}+d$.* R. G. THOMAS† AND T. LAURITSEN, *California Institute of Technology.*—When C^{13} is bombarded with deuterons the reactions $C^{13}(d\ \alpha)B^{11}$, $C^{13}(d\ n)N^{14}$, and $C^{13}(d\ p)C^{14}$ occur. A neutron group[1] indicating a level in N^{14} at 5.1 ± 0.3 Mev and a proton group[2] corresponding to a level in C^{14} at 5.2 ± 0.3 Mev have been reported. Gamma-radiation of 5.5 Mev accompanying these reactions has been observed.[1,3] In an attempt to obtain more precise information on the γ-radiation we have bombarded a carbon target, enriched to 50 percent C^{13}, with 1.42-Mev deuterons and observed the secondary electrons with a magnetic lens spectrometer of 2 percent resolution and $2\frac{1}{2}$ percent solid angle. Photoelectrons from a thorium converter indicate γ-rays of 3.4, 2.3, 1.6, and 0.73 Mev in addition to the known lines from $C^{12}+d$ at 3.1 and 0.51 Mev. Secondary Compton electrons from a beryllium converter indicate γ-rays of 3.4, 5.1, 5.7, and 6.1 Mev. There is some indication of a weak γ-ray of 3.9 Mev.

* This work was assisted by the Joint Program of the ONR and the AEC.
† AEC Fellow.
[1] W. E. Bennett, *et al.*, Phys. Rev. **59**, 781 (1941).
[2] R. F. Humphreys and W. W. Watson, Phys. Rev. **60**, 542 (1941).
[3] T. W. Bonner, *et al.*, Phys. Rev. **59**, 214A (1941).

D14. The Low Energy α-Particles from $F^{19}(p\alpha)O^{16}$.* C. Y. CHAO, A. V. TOLLESTRUP, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.**—We have recently determined the energies and intensities of four low energy α-groups from the reaction $F^{19}(p\ \alpha)O^{16*}$ at the resonances between $E_p = 300$ kev and 1400 kev. The proton beam was produced by an electrostatic generator, the target was a thin layer of ZnF_2 deposited on a copper strip and the α-particles emerging at 138° were analyzed by a double-focusing magnetic spectrograph. The Q-values of the four groups are found to be $Q_0 = 2.057 \pm 0.010$, $Q_1 = 1.977 \pm 0.008$, $Q_2 = 1.204 \pm 0.008$ and $Q_3 = 1.002 \pm 0.008$ Mev, corresponding respectively to the pair level and the three γ-ray levels. These Q-values when added to the corresponding pair energy or γ-ray energy recently obtained by Rasmussen, Hornyak, Lauritsen, and Lauritsen[1]

give an average value of $Q=8.101\pm0.030$ for the reaction $F^{19}(p\,\alpha)O^{16}$. The relative intensities of the three α-groups preceding γ-ray emission are found to vary considerably from resonance to resonance. We have measured the γ-ray intensity simultaneously with the measurement of α-particles. By assuming isotropic angular distributions, the ratio of the total number of α-particles to that of γ-rays is found to be very close to unity at all the α-ray resonances investigated.

* Assisted by the joint program of the ONR and the AEC.
‡ To appear in the Phys. Rev.

FRIDAY MORNING AT 9:30

Room 372, Physics Department

(D. L. WEBSTER, presiding)

E1. Production and Annihilation of Antiprotons. C. W. HELSTROM, *California Institute of Technology.*—The cross section for the reaction: negative meson+proton→antiproton +neutron+proton, has been calculated by the usual perturbation theory. The threshold energy is 4μ, where μ=rest energy of the proton. The cross section reaches a maximum of $\sim0.06(g^2/\hbar c)r^2$ at an incident meson energy of 25μ, and then drops off g=meson coupling constant; $r=g^2/\mu$. The cross section for production of neutron-antiproton pairs in nucleon-nucleon collisions has been calculated by the Weizsäcker-Williams method. The cross section is $\sim0.01(g^2/\hbar c)^2r^2$ in the region of 30-Bev incident nucleon energy. The antiproton may be annihilated by collision with a proton to form a pair of charged mesons; the cross section is $2\pi r^2c/v$ non-relativistically, where v=velocity of the incident antiproton. Annihilation into a pair of neutral mesons vanishes as v/c. The cross section for the process: neutron+antiproton→negative meson+neutral meson is $4\pi r^2c/v$ at low energies. Bound in the Coulomb field of a proton, the lifetime against annihilation into charged mesons is $\sim10^{-17}$ sec. in the singlet ground state or $\sim10^{-8}$ sec. in the triplet state. The pseudoscalar interaction has been used in all these calculations. This work is being carried on under a fellowship of the E. I. du Pont de Nemours Company.

E2. Further Remarks on Neutron Optics. OTTO HALPERN AND CHARLES B. SHAW, JR.,* *University of Southern California.*—The previously[1] given theory of neutron refraction and double-refraction has been extended to cover those cases in which capture and *incoherent* scattering processes are also present. These processes can be formally accounted for by the introduction of a complex index of refraction. In close analogy to the electromagnetic case total reflexion at the critical angle becomes imperfect in the presence of an index of absorption. This effect is of some importance in the production of polarized neutron beams by total reflexion, an experiment suggested a year ago[2] and recently carried[3] out by using Co[4] as reflector. The extended theory may also be useful for the interpretation of total reflexion experiments carried out with strong absorbers like Cd, the scattering cross section of which is difficult to determine. In some modifications of H the large incoherent cross section will influence the results of experiments dealing with refraction and reflexion phenomena.

* Now at the University of Chicago.
[1] Halpern, Hamermesh, and Johnson, Phys. Rev. **59**, 981 (1941).
[2] O. Halpern, Phys. Rev. **75**, 343 (1949).
[3] J. Hughes and M. T. Burgy, Phys. Rev. **76**, 463 (1949).
[4] M. Hamermesh, Phys. Rev. **75**, 1766 (1949).

E3. A Proposed Decay Scheme for $_{72}Hf^{181}$ (46 day, 5.7 hour). S. B. BURSON AND K. W. BLAIR, *Argonne National Laboratory.*—A determination of the radiations of $_{72}Hf^{181}$ (46 day) has been made by absorption and coincidence methods. Upon delaying one couter 8.5 microseconds ($\tau=7.25$ μsec.) aluminum absorptions indicate a delayed beta of 0.40 Mev coinciding with several conversion electron groups. This, together with the absence of delayed gamma-coincidences, indicates that the beta leads directly to the 22-microsecond isomeric state of $_{73}Ta^{181}$. Absorptions of the conversion electrons coinciding with the delayed beta indicate energies corresponding to the 0.47, 0.34, and 0.13-Mev gamma-rays previously reported by others from spectrographic data. A 5.7-hour beta-activity in hafnium (C. O. Muehlhause, ANL-4097) was also examined and tentatively assigned to an isomeric state of Hf^{181}, approximately 0.087 Mev below the 46-day state. Absorption in lead of the photon radiations of this period is indistinguishable from that of the 46-day period. No delayed coincidences accompanied this activity. Absorptions in aluminum of the prompt $\beta-\rho^-$-coincidences indicate that a beta of about 0.45 Mev coincides with electron groups similar to those observed in the 46-day period. A decay scheme is proposed.

E4. Proton-Proton Scattering at 12.5 Mev.* BYRON T. WRIGHT AND F. E. FARIS,† *University of California, Los Angeles.*—A scattering camera having complete cylindrical symmetry about the proton beam direction has been constructed. An annular-shaped film on whose surface are latent circular reference lines is placed in the camera with its plane perpendicular to the beam direction. For a particular point on the film the angular range within which scattered protons can be received is defined by the edges of an annular slit which lies between the film and the hydrogen filled scattering volume. Background due to protons is limited to those which are successively scattered by three slit edges. A Faraday cup in a separate chamber is used to integrate the beam and to measure its integral range in Al curve. To date the differential cross section at 90 degrees (c.m.) at 12.5 Mev has been observed. These results are being analyzed and will be presented.

* This work was supported in part by the Joint Program of the ONR and the AEC.
† Now with North American Aviation, Inc.

E5. High Energy Scattering—Theoretical. RICHARD S. CHRISTIAN, *University of California, Berkeley.*—The 280-Mev $n-p$ scattering[1] experiments are in agreement with the predictions of the potential models[2] proposed on the basis of scattering below 90 Mev, showing that large velocity dependent forces are not present. The 350-Mev $p-p$ results,[3] however, show an anomalously high and flat cross section. The flatness of the cross section cannot be interpreted in terms of a primarily S-way interaction, since the magnitude is some 10 times larger than expected and twice $4\pi\lambda\!\!\!^{-2}$. Since central forces tend to concentrate the scattering in a forward cone ($\sim$15–20°), the only possible interpretation is by means of a very short range tensor force, e.g., calculations show that an $\exp(-r/R)/r^2$ tensor radial dependence ($R\sim2\times10^{-13}$ cm) gives agreement at 350 Mev without altering the low energy

agreement. The essential feature of this model appears to be a strong tensor interaction at distances less than 0.5×10^{-13} cm. This work was sponsored by the AEC.

[1] Kelly, Leith and Wiegand, Phys. Rev. **76**, 589(A) (1949), and private communication.
[2] R. Christian and E. W. Hart, in press.
[3] O. Chamberlain and C. Wiegand, private communication.

E6. A Multiple Scattering Deflector for the 184-Inch Cyclotron. C. E. LEITH, *University of California, Berkeley.*—The electromagnetic deflector[1] for the 184-inch cyclotron provides a deflected 350-Mev proton pulse of 0.1 μsec. duration with a repetition rate of 60 cycles. The short duration of this pulse makes it difficult to use counters of existing types in doing many types of particle experiments. A deflector system will be described which lengthens the proton pulse duration to 50 μsec. maintaining the same repetition rate. A 0.1-cm thick Th scatterer is placed at the position usually occupied by the electric deflector. Some of the protons multiply scattered in passing through the Th experience the correct deflection to allow them to enter the magnetic channel and thus be brought out of the cyclotron. The time average proton current obtained in this way outside of the main shielding is 10^{-12} ampere in a 2.5-cm diameter beam. This current is 10^{-2} times that obtained with the electric deflector. It will be shown that this deflector system is applicable at any energy. This development was sponsored by the AEC.

[1] W. M. Powell *et al.*, Rev. Sci. Inst. **19**, 506 (1948).

E7. Absorption of π^--Mesons in Hydrogenous Materials. W. K. H. PANOFSKY AND H. F. YORK, *University of California, Berkeley.*—A π^--meson captured in hydrogen cannot convert the proton into a neutron without emission of an additional particle, presumed to be a 130 Mev γ-ray. This γ-ray was looked for using the pair spectrometer of Bjorklund, Crandall, Moyer, and York.[1] π^--produced in the target of the 184-inch cyclotron were captured in CH_2 and LiH converters. Using the absolute cross section for meson production as determined by Richman and Wilcox[2] the expected γ-ray yields were calculated. The results indicate that, if the γ-ray process occurs, less than 1 part in 1000 of the π^- captured in CH_2 are converted on H and less than 1 part in 200 of the π^- captured in LiH are converted on H. Studies using high pressure hydrogen are in progress. This work was sponsored by AEC.

[1] Bjorklund *et al.*, Phys. Rev. (to be published).
[2] Private communication.

E8. High Energy Photons from Proton Nucleon Collision. W. E. CRANDALL, B. J. MOYER, AND H. F. YORK, *University of California, Berkeley.*—The yield and energy spectrum for high energy photons from a target bombarded by protons of energy over 175 Mev in the 184-in. cyclotron are presented here. For 345-Mev protons, the energy spectra for various angles of observation, when transformed to a system with $\beta=0.32$ in the direction of the incident proton beam, become identical. A calculation of the absolute yield, based on spherical symmetry in this unique system, gives a cross section of 1×10^{-27} cm² per carbon nucleus. The peak of the energy spectrum curve in this system comes at approximately 75 Mev. Possible sources of this radiation have been considered. Nucleon isobars appear to be ruled out since nucleons with energy of 250 Mev would be required in the nucleus. Bremsstrahlung neither fits the shape of the energy spectrum nor the magnitude of the yield for protons above 200 Mev. Excited π-mesons appear unlikely due to energy balance considerations. Neutral mesons, with a rest mass of 300 ± 25 electron masses and a lifetime of less than 10^{-11} sec., decaying into two photons seem to fit all data observed. This development was sponsored by AEC.

E9. Non-Equilibrium Cyclotron Orbits. WALTER H. BARKAS,* *University of California, Berkeley.*—Trajectories are described in cylindrical coordinates (r, ϕ, z). Equilibrium orbits exist in the median plane $(z=0)$ only with momenta $p=mr\dot{\phi}=(e/c)rH_z(r,0)$. The vector potential contains one component $A_\phi(r,z)\equiv A$, and ϕ is an ignorable coordinate. The general motion in the (r,z) plane is derivable from a scalar potential,

$$U=\frac{1}{2m}\left(\frac{Q}{r}-\frac{e}{c}A\right)^2,$$

leading to a "boundary of libration" $[\pm p+(e/c)A]r=mr_1^2\dot{\phi}_1+(e/c)r_1A_1=Q$, where the subscript 1 refers to any point on the orbit. In the median plane

$$p=e\int_{r_1}^{r_2} rH_z dr/c(r_1\cos\lambda_1-r_2\cos\lambda_2),$$

where the subscripts refer to two points on the trajectory, and $\tan\lambda=1/r(dr/d\phi)$. The orbit in the median plane is:

$$\phi=\arcsin\left[\frac{(R_2-R_1)\sin\tau}{2r}\right]+a_0\tau+\sum_{n=1}^{\infty}a_n\sin n\tau,$$

with

$$\cos\tau=\frac{R_2^2+R_1^2-2r^2}{R_2^2-R_1^2},$$

R_1 and R_2 being the limits of libration. The a_n and the libration limits are evaluated from $A_\phi(r,0)$, together with the observed values of r_1, r_2, λ_2, and $\phi_2-\phi_1$. λ_1 is then determined from the orbit equation. Accurate calculation of particle momenta for the determination of meson masses is the immediate purpose of this work. This work was sponsored by AEC.

* ONR, San Francisco, California.

E10. Ratio of Positive to Negative π-Meson Yields from Various Targets Bombarded by 345 Mev Protons. H. BRADNER AND S. B. JONES, *University of California, Berkeley.*—Nuclear plate techniques have been used to investigate the yields of high energy mesons produced in various targets by 345 Mev protons. Fifty Mev π^+- and π^--mesons which leave the target at 90° to the incident beam direction are bent in opposite directions by the cyclotron magnetic field, and pass through channels in a copper block. The mesons are then slowed down in an absorber, and finally recorded in nuclear emulsion plates. Neglecting possible differences in nuclear absorption of π^+- and π^--mesons, the ratio of yields can be obtained by counting the relative numbers of π^+- and π^--mesons in equal volumes of emulsions in the two plates. Preliminary results give π^+/π^--ratios of 2.7 ± 2 for Be, 4.8 ± 0.5 for C, 5.4 ± 1 for Al and 4.3 ± 2 for Cu. The errors quoted are statistical probable errors. This work was sponsored by AEC.

E11. Phenomenological Interpretation of $p-p$ Scattering at 32 Mev. H. P. NOYES, *University of California, Berkeley.*—Analysis of linear accelerator data on 32 Mev $p-p$ scattering in terms of static potentials indicates qualitative differences between $n-p$ and $p-p$ nuclear forces. The angular distribution is compatible with pure ^1S scattering of phase shift approximately 50°, but customary static potentials predict additional ^1D scattering incompatible with the data. Central scattering in odd (triplet) states cannot resolve this discrepancy but tensor force scattering in odd states is peaked at 90°. Hence the D wave can be masked by a tensor force with the same magnitude of angular variation although this raises the total cross section. A tensor potential of about half the magnitude of the singlet potential, when added to the exponential well given by Blatt and Jackson[1] as the best fit at low energies, gives the correct angular dependence without destroying the agreement at lower energies. This model gives an absolute magnitude about 5 percent too high which could be lowered by using a well slightly shallower than the exponential,

or by using different radial dependence in singlet and triplet states. This work was sponsored by AEC.

[1] J. M. Blatt and J. D. Jackson, Phys. Rev. (to be published).

E12. Auger Effect in the Decay of At^{211}. LAWRENCE S. GERMAIN,* *University of California, Berkeley.*—At^{211} decays by both K capture and alpha-particle emission. The K capture decay leads to Po^{211} which emits an alpha-particle with a half-life of 5×10^{-3} second. It has been possible to record the At^{211} activity in photographic emulsions by soaking the plates in a water solution containing the At activity. Both the 5.92 Mev At^{211} alpha-particles and the 7.34 Mev Po^{211} alpha-particles were visible in the plates and easily distinguished by their characteristic ranges. Some of the Po^{211} alpha-tracks were found to have a short electron track at one end. These electrons had the proper energy to be Auger electrons from the K capture decay at At^{211}. The number of Po^{211} alpha-tracks associated with short electrons divided by the total number of Po^{211} alpha-tracks gives the fraction at At^{211} K capture decays which give rise to Auger electrons. This ratio, which is the percent internal conversion of the K x-rays, was found to be (9.25 = 0.50 percent). Some evidence was found to indicate that Bi^{207}, the result of the alpha-decay of At^{211}, decays by K capture. This work was sponsored by AEC.

* Now at Reed College, Portland, Oregon.

E13. An Iteration Procedure in the Rayleigh-Ritz Principle. E. GERJUOY, *University of Southern California,* AND HAROLD GRUEN, *University of California, Los Angeles.**—Let H be an operator whose ground state energy is E_1, and φ a trial function such that the integrals $(\varphi, H^r\varphi)=(H\varphi, H^{r-1}\varphi)=\cdots(H^r\varphi, \varphi)$ exist and are equal for any positive integer r. Define $\Gamma_A\equiv H-A$ and $\beta_n(A)\equiv(\varphi, \Gamma_A{}^n\varphi)$, where A is a parameter. Then $E_1\leqslant A+\beta_2/\beta_2=F_2(A)$. Moreover, $F_2(A)$ has a single minimum. If this minimum occurs at A', then $F_2(A')\leqslant(\varphi, H\varphi)/(\varphi, \varphi)$. The equality holds only if φ is an eigenfunction. Since $F_2(A)=(\Gamma_A\varphi, H\Gamma_A\varphi)/(\Gamma_A\varphi, \Gamma_A\varphi)$, the function $(H-A')\varphi=\varphi^1$ may be regarded as a new trial function, superior to φ, and in fact the best function of the class $\Gamma_A\varphi$. Repeating the process of minimizing F_2 using the new trial function φ^1, a decreasing sequence of upper bounds to E_1 is obtained, which presumably converges to E_1 if $(\varphi, \psi_1)\neq0$, where ψ_1 is the ground state wave function of H. Since φ can often be chosen so that the integrals $(\varphi, H^r\varphi)$ are readily evaluated, this procedure may prove useful. Possible applications will be discussed. If $F_n(A)\equiv A+\beta_n/\beta_{n-1}$, n odd, and if its (only) minimum occurs at A_0, then it follows that $E_1\leqslant F_n(A_0)\leqslant(\varphi, H\varphi)/(\varphi, \varphi)$. Thus the functions F_n can also be used to generate improved estimates of the ground state.

* Junior Fellow of the National Bureau of Standards, Institute for Numerical Analysis, University of California, Los Angeles, California.

FRIDAY MORNING AT 9:30

Room 392, Physics Department

(PAUL KIRKPATRICK, presiding)

F1. Mass Spectrometric Studies of Oxide Cathode Sublimation Phenomena.* R. H. PLUMLEE, *Radio Corporation of America.*—Mass spectrometric techniques have been utilized to study sublimation characteristics of materials used in electron tubes. General processes induced thermally and by electron bombardment have been studied as well as specific phenomena characteristic of individual materials. Preliminary results noted include (1) the inefficiency of electron bombardment for producing material transport, (2) the complex thermal evaporation of oxide cathode constituents, (3) the absence of positive ion evaporation from oxide cathodes, (4) confirmation of mechanisms for negative ion formation in vacuum systems, and (5) the liberation of molecular oxygen from oxide cathodes as a function of electron emission.

F2. New Bands in the $3p^1\Pi-ls^1\Sigma$ System of the Hydrogen Molecule. C. R. JEPPESEN AND PAUL E. PFLUEGER, *Montana State University.*—The absorption spectrum of hydrogen has has been re-examined with a view to observation of new bands associated with the normal electronic state. At very low pressures, only the $3p^1\Pi-ls^1\Sigma$ progression having v' greater than 2 is observed. This progression, discovered by Hopfield,[1] occurs in great strength because of pre-dissociation in vibrational states having v' greater than 2. At higher pressures this absorption becomes continuous, making observation of other systems impossible. The 0−0, 1−0, and 2−0 bands of this system were observed for the first time, however, and their rotational analysis confirms the previous study[2] of ten emission bands of this system.

[1] J. J. Hopfield, Nature **125**, 923 (1930).
[2] C. R. Jeppesen, Phys. Rev. **54**, 68 (1938).

F3. The Sensitivity of a Positive Ion Space Charge Detector.* R. R. EGGLESTON AND G. L. WEISSLER, *The University of Southern California.*—In order to measure photoionization in N_2 and other gases as a function of wavelength in the vacuum ultraviolet, it was thought that the "Kingdon Cage" positive ion space charge detector[1] would be most apt; particularly since this instrument is only sensitive to positive ions and will not be affected by stray electrons. A preliminary study was made to investigate its sensitivity by generating a known number of positive ions in the gas within the detector diode (N_2 at 8.8×10^{-3} mm Hg) and plotting this number against the deflection of a bridge galvanometer. With 8 volts across the diode we were able to detect of the order of 50 positive ions present at any instant. This last figure was arrived at by using estimates of positive ion life times following a procedure suggested by Kingdon.[1] Since the present rough data were obtained with very simple equipment, it seems indicated to follow up Kindgon's work on ion life times with modern oscillographic techniques, and to enhance the sensitivity of the detector by use of resonant—and/or pulse-amplifiers in the bridge circuit.

* This work is being carried on under an ONR contract.
[1] K. H. Kingdon, Phys. Rev. **21**, 408 (1923).

F4. The Influence of the Piezo-Electric Effect on Tribo-Electrification.* JOHN W. PETERSON, *University of California, Berkeley* (introduced by Leonard B. Loeb).—The piezo-electric effect has been suggested as a possible explanation for tribo-electric charging in cases where at least one piezo-electric crystalline material is involved.[1] To investigate this suggestion, measurements have been made of the charge acquired by amorphous quartz particles in sliding over a crystalline quartz plate, which can be compressed to give the desired piezo-electric surface charge. The quartz particles average 400 microns in diameter, receiving an average negative charge of 4×10^4 electrons per particle with zero surface charge on the

plate. The same amount of charge is transferred from either positive or negative surface charges, and this amount does not exceed twelve percent of the total surface charge of the plate. With maximum surface charge, the piezo-electric contribution to the charge of the particles is less than twenty percent of their total charge.

* These studies supported by ONR Funds.
[1] L. B. Loeb, Science, 102, 573 (1945).

F5. The Electrical Charges on Dust Particles.* W. B. KUNKEL, *University of California, Berkeley* (introduced by Leonard B. Loeb).—A method for the determination of the charge and size of falling droplets developed by Hopper and Laby was used to measure the charges on the individual particles of large samples of dispersed powders. The behaviour of various materials as well as the effect of different methods of dispersion were investigated. Practically all particles proved to be charged, both positive and negative signs occurring simultaneously. When any contact between dissimilar substances was avoided, the charges balanced, leaving the cloud neutral. In these cases the average charge per particle was roughly proportional to the surface area of the particles independent of the method of dispersion. No difference in polarity between large and small particles was noted. No effect of humidity could be discovered, mainly because of the remarkable invariance of the moisture content of such fine non-hygroscopic powders. When different powders were mixed, the charge distribution showed marked asymmetry. When the dusts were blown against different surfaces mainly the larger particles displayed a predominance of one sign. Magnitude and sign of the excess charge depended on the substances and processes involved. In addition to this study the equilibrium charge distribution in coarse aerosols was investigated.

* These studies supported by ONR Funds.

F6. Choice of Gap Forms for Corona Breakdown Studies and the Electrostatic Field in a Point-to-Plane Gap.* L. B. LOEB, J. H. PARKER, E. E. DODD, AND W. N. ENGLISH, *University of California, Berkeley.*—Various electrode geometries are discussed with reference to their suitability for quantitative laboratory investigations of corona discharge phenomena so that the use of a convenient geometry to standardize data can be recommended. The recommended geometry is the "point-to-plane" gap consisting of a hemispherically capped circular cylinder of 0.025 or 0.050 cm radius at a gap length 160 times its radius from a perpendicular plane. In order to evaluate the Townsend integral involved in the threshold theories for the various phenomena, the axial electrostatic field intensity for the point-to-plane gap is needed so that the first Townsend coefficient can be determined. An approximation method is employed which yields the desired field to ± 1 percent as a table of values at various points in the gap. The resulting Townsend integrals at experimentally determined pre-onset burst pulse threshold for the point-to-plane gap and for the confocal paraboloid gap are compared and found to be in relatively good agreement.

* These studies supported by ONR Funds.

F7. Point-to-Plane Corona Studies in Dried Air.* H. W. BANDEL, *University of California, Berkeley* (introduced by Leonard B. Loeb).—A current, visual, and oscilloscopic study of point-to-plane corona in dried air has been made to obtain a comprehensive set of consistent data, and to compare with the work of Miller[1] using co-axial cylinders. Polished, hemispherically capped platinum points of 0.25, 0.5, and 1.0 mm diameter have been used, with gap length to point radius ratio of 160, for a series of seven pressures from atmospheric to 10 mm Hg, and from low voltages up to breakdown. A thorianite ore source of gamma-rays was used for triggering, and with negative points comparison work has been done using ultraviolet light. In dried air with positive points it was found that pre-onset streamers occur only with higher pressures and larger points in agreement with the Loeb-Meek streamer theory and the known high absorption of ultraviolet by water vapor. Under some conditions, with larger negative points at high voltage the discharge undergoes a transition from the characteristic Trichel pulse corona to a Townsend type discharge with no pulses and no Faraday dark space.

* These studies supported by ONR Funds.
[1] Charles G. Miller, PhD. Thesis, University of California, 1949.

F8. Mass Measurements of Cosmic-Ray Particles.* T. C. MERKLE, JR., E. L. GOLDWASSER, AND R. B. BRODE, *University of California, Berkeley.*—The analysis of mass measurements of the particles in the cosmic radiation at sea level indicates that under a 6-inch wooden roof about as many protons as mesons are found in the energy region below 300 Mev. The presence of some heavy particles with ranges and curvatures that indicated masses of about 1000 Me were also observed. However, the relative number of these particles copared with protons has been found to depend on the quality of no field control tracks observed. The distortions observed are not statistical in the sense that most of the no field controls show curvatures of less than $1/60$ M^{-1}. However, among these tracks appears an occasional control track with a positive curvature of $1/10$ M^{-1}. Because of the non-statistical character of the observed curvature distortions, it is possible to be misled as to the quality of the tracks by taking too few control observations. The combination of a few of the $1/10$ M^{-1} distortions with the proton tracks appears to account for the particles of apparent mass of about 1000. It has been found possible, by control of such factors as temperature gradients, rubber diaphragm tension, vapor saturation and speed of expansion, to operate the chamber for periods of many days with no control track showing curvatures over $1/30$ M^{-1}. In these periods, no particles of apparent mass of 1000 have been observed.

* Assisted by the Joint Program of the ONR and the AEC.

F9. The Ratio of Positive to Negative Particles in the Cosmic Radiation at 3650 Meters Elevation.* R. B. BRODE, *University of California, Berkeley.*—The ratio of positive to negative particles in the cosmic radiation has been measured at an elevation of 3650 meters on White Mountain, California. This ratio has been measured for particles that have a range in iron of over 60 cm and a momentum of from 1.0 to 2.5 Bev/C. The values observed for this ratio for the vertically incident radiation are 1.32 ± 0.02 at 100 meters elevation; 1.30 ± 0.03 at 3650 meters; and 1.32 ± 0.03 at 3650 meters, under an absorbing layer of 45 cm of lead. This amount of lead is equivalent to the atmosphere between 100 meters and 3650 meters. A series of observations at 34° and 56° from the vertical in the east and west directions is partially completed and results on these measurements will be reported.

* Assisted by the Joint Program of the ONR and the AEC.

F10. Production of Penetrating Showers in Carbon.* JOHN R. GREEN AND W. B. FRETTER, *University of California, Berkeley.*—During the summer of 1949, pictures were obtained of penetrating showers producing in carbon at 3650 meters on White Mountain, California. The cloud chamber had an illuminated region of $18''\times22''\times5''$, contained ten 1" graphite plates with four $\frac{1}{2}''$ lead plates underneath them for identification of penetrating particles, and was filled with argon and sufficient pure alcohol for saturation. The actuating system required that at least one particle enter at the top of the chamber, and that at least three (or, if desired, two) particles emerge from 2" of lead underneath the chamber. Analysis of but a small number of the penetrating showers observed indicates a high probability that one or more of the

particles produced will initiate a secondary event, such as a second penetrating shower, a burst or star, or an abnormal scattering. There is also indication that the production of penetrating particles might at times be accompanied by direct production of electrons or of other particles that introduce electrons into the shower very near the initial event. Most of the penetrating showers included gamma-rays which produced electron pairs or showers farther down in the carbon and lead plates.

* Assisted by the Joint Program of the ONR and the AEC.

F11. Extensive Showers under Water.* W. B. FRETTER AND JOHN ISE, JR., *University of California, Berkeley.*—Although there is considerable evidence that multiple electronic cores separated by appreciable angles occur in penetrating showers, attempts to find multiple cores in air showers have failed. It has been proposed that the cores, if they exist, are concentrated in a region of a meter or two in diameter where the high density of particles makes the analysis by counters or ionization chambers difficult. As an air shower passes into water, however, the lower energy particles are absorbed and after a *density* (not z-dependent) transition effect the entire shower might be concentrated in a very small area. Thus multiple cores separated by small distances might be detected under water. A preliminary experiment to investigate air showers under water has been done in a lake at an elevation of 7500 feet. Counting rates were taken under 9 feet of water as a function of distance between counter trays. Fourfold coincidences, requiring two particles in each tray and twofold coincidences requiring one particle in each tray were taken. No striking effect was found, but counting rates were high and the experiment seems promising if greater depths of water are used.

* Assisted by the Joint Program of the ONR and the AEC.

F12. Photographic Evidence for the Existence of a Meson of More than 450 Electron Masses. HARRIET H. FORSTER, *University of Southern California.*—Photographs will be presented of a cosmic-ray event in which a charged particle comes to rest in the emulsion of a photographic plate and produces a nuclear disintegration with the emission of at least eleven charged particles. On the basis of grain density and scattering one of the emitted particles can be identified as a meson, presumably a π-meson. A calculation of the excitation energy of the disintegrating nucleus based on the energies of the particles stopping in the emulsion gives a lower limit of 450 or 525 electron masses for the rest mass of the incident particle depending whether the emitted meson was a μ- or π-meson. The range together with the range energy relations for charged particles in the photographic emulsion permits placing a lower limit of 10^{-12} sec. for the lifetime of the incident meson. The even which was found in an Ilford C_2 plate exposed for several hours at 30,000 ft. will be discussed in detail. Special reference will be made to heavy mesons reported by other investigators.[1]

[1] C. R. LePrince-Ringuet, Rev. Mod. Phys. **21**, 42 (1949).

F13. Preliminary Results—Operation of a High Power Electron Linear Accelerator.* R. F. POST, *Stanford University.*—Electrons have been accelerated with a new 12 foot "Prototype" electron linear accelerator. This accelerator is designed to reach an ultimate energy of 60–70 Mev with large peak beam currents. The accelerator is intended as a prototype section of the 1-Bev electron accelerator under construction at Stanford.

* This project is supported by ONR, Contract N6-onr-25116.

F14. Theory of the No Load Characteristics of Saturable Reactors with Hysteresis, I. ALFREDO BAÑOS, JR. AND WILLIAM B. MCLEAN, *University of California, Los Angeles, and U. S. Naval Ordnance Test Station, Inyokern.*—Renewed interest in the characteristics of saturable reactors, particularly in their application to magnetic amplifiers, stems from the remarkable magnetization properties exhibited by recently developed materials known commercially as Mumetal, Orthonol, Deltamax, etc. These materials have in common a very narrow hysteresis loop rising almost vertically to a sudden and very flat saturation curve. Heretofore, all attempts to predict theoretically the performance of such a saturable reactor with a spirally wound core of any of these materials (a) have assumed no hysteresis, and (b) have endeavored to approximate the d.c. magnetization curve by means of empirical formulas or by means of straight line segments. In either case, assuming an alternating e.m.f. applied to the primary winding, one wishes to obtain the Fourier coefficients of the currents flowing in the primary and secondary windings as well as in the rather important d.c. bias winding. Without neglecting hysteresis and approximating the $B-H$ curve and hysteresis loop of these materials by means of straight line segments we have been able to compute the Fourier coefficients mentioned above in terms of a minimum number of parameters; namely, the residual magnetization B_r, the coercive force H_c, and the slopes μ_1 and μ_2 of the saturation and rising portions of the idealized magnetization curve respectively. The results presented here consider separately the cases of maximum induction above and below the "knee" of the magnetization curve as well as the effect of d.c. bias. In a later paper we propose to present a comparison between the theory and measurements now in progress at the Naval Ordnance Test Station.

FRIDAY AFTERNOON AT 2:00

Little Theater

(L. I. SCHIFF, presiding)

Invited Papers

G1. The Stanford University Microwave Laboratory. MARVIN CHODOROW, *Stanford University.* (30 min.)

G2. The Fine Structure of Singly Ionized Helium. MIRIAM SKINNER, *University of California, Berkeley.* (30 min.)

G3. Application of Magneto-Hydrodynamics to Cosmic-Ray Physics and Geomagnetism. EDWARD TELLER, *University of Chicago (now at Los Alamos Scientific Laboratory).* (30 min.)

SUPPLEMENTARY PROGRAMME

SP1. Heat of Dissociation of Nitrogen.*† JOSEPH KAPLAN, *University of California, Los Angeles.*—A new method is presented for selecting between the Herzberg value of 7.384 ev for the heat of dissociation (D) of nitrogen molecules ($N_2 X^1\Sigma$) into normal nitrogen atoms (^4S), and Gaydon's value of 9.764 ev. This is based on an experimental proof that the $A^3\Sigma$ level of N_2 dissociates into one normal and one excited atom. It would have to dissociate into normal atoms if D were 9.76 ev. This experimental proof is the result of observations which show that those Vegard-Kaplan bands which originate on $v'=0$ are observed in auroral afterglows only when atomic recombination is taking place, and when metastable atoms in *either* the ^2P or ^2D levels are involved. If the products of dissociation of the $A^3\Sigma$ level are ^2P and ^4S, and $D=7.38$ ev, the Birge-Sponer extrapolation for this level is then too small by 0.08 ev. If the products of dissociation are ^2D and ^4S, the extrapolation is too great by 1.10 ev. This is a reasonable excess. On the basis of these interpretations of auroral afterglow spectra, the Herzberg value of 7.384 ev appears to be the correct one.

* Work done under contract with ONR.
† To be given after Session A if time permits.

SP2. A Constant-Mass Electron in Uniform Fields.* F. W. WARBURTON, *University of Redlands.*—The reciprocal force of relative electrodynamics expressed in a power series of $1/c$,[1] describes apparent increase in mass in deflection experiments in uniform fields. In the uniform electric field E_z between condenser plates, the force reduces to

$$F_z = Ee[1+(\dot{x}^2+\dot{y}^2+\dot{z}^2)/2c^2-2b\dot{z}^2/c^2 + (4b-1)(d/2-z)[(\partial z^2/\partial t^2)^2]/c^2+\cdots].$$

The coefficient $b=\frac{1}{2}$ provides the decreased force replacing increased mass, and gives increased force as the electron decelerates at the target. A similar expansion in a uniform magnetic field **B** involves the $1/c^4$ terms including the acceleration factor $\mathbf{f}/c^2$ as well as those containing the relative factor v^2/c^2. In balanced fields with **v** transverse to **E** and to **B** the acceleration terms are zero. In the magnetic field alone the centripetal acceleration terms combine with the v^2/c^2 terms. Comparison with experiment then determines another coefficient in the series.

* To be given after Session G if time permits.
[1] F. W. Warburton, Phys. Rev. **69**, 40 (1946).

Author Index to Papers Presented at the Stanford Meeting

To avoid serious delay in the appearance of the Bulletin, joint papers are indexed only under the name of the first author.

Aamodt, Lee, Vincent Peterson, and Robert Phillips—No. D6
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Davis, Leverett, Jr.—No. B11
Eggleston, R. R. and G. L. Weissler—No. F3
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